Fermilab

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SUMMARY OF THE FIRST 5 MONTHS AT B12

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Purpose

To investigate the problem areas of building, installing and operating a cryogenic system that would serve as a prototype for superconducting magnets. Design of the system is such that the 4.5°K refrigeration system is located remotely from the superconducting magnets.

Description

Located on the Main Ring road at B12 is a mini-Superconductor prototype system which consists of 160 watts of refrigeration, transfer line, and two magnets ("C" Series 2½ ft #2 and "C" Series 10 ft #2). The refrigeration consists of 2 CTi 1400 cold boxes, one of which was modified by Fermilab to also produce 20° high pressure refrigeration for magnet heat shield intercepts. They are fed by 5 - 50 SCFM compressors in parallel. The 25m transfer line shown in Fig. 1 carries a superconducting power bus in the 1Ø pipe. The colder 2Ø return pipe surrounds the 1Ø supply which makes the entire line a heat exchanger, thus providing subcooled liquid helium to the superconducting magnets located within the Accelerator enclosure some 25m away from the liquefier.

The transfer line/magnet loop was built in 3 sections at Lab 2; they are 40 ft horizontal transfer line, 25 ft vertical line, and 25 ft horizontal section which contains cryogenic lines, magnet and JT valve. The subassemblies were pretested and then set in place on April 30, 1975. They were field welded and tested, with cooldown starting on May 8.

Operation

On May 15 the C2.5-2 magnet was powered to 20kG (450GeV) and a 1.6μsec, 100 GeV beam of 1.0×10^{12} ppp deflected into the beam stop. The following week we shut down to replace the power leads which were malfunctioning. On May 30 cooldown was reinitiated. During the next month and a half we debugged our instrumentation and made three cryogenic data runs, the contents of which are given in Table I. We discovered that the film coefficient of heat transfer to our vapor pressure thermometer bulbs (VPT) was so low that a mere 0.025 watt of heat leak down the capiliary tube, destroys the accuracy of the instrument. On critical VPT's we have now installed a liquid nitrogen intercept which reduces the heat leak to ~0.005 watts. The technique of making heat leak measurements is covered in TM-624.

On July 16 the first 10 ft magnet was completed so warmup of the 2½ ft magnet was begun. We then used the 8 hour Thursday shutdowns to install the new magnet. The time breakdown is as follows:

4 hr Cutting C2.5-2 apart from transfer line.
4 hr Move C2.5-2 and hang C10-2.

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8 hr Modify line and C2.5-2 to new interface design.
8 hr Modify C10-2 to match existing design.
8 hr Modify C10-2 design to eliminate bellows failure.

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4 hr Making 2 electrical splices, etc.
4 hr Closing up boxes.
12 hr Cold shocking and vacuum testing.

6½ shifts of 8 hr with a 7 man average crew.

On Sept. 10 we started cooldown but after a week of running we were not able to achieve subcooled liquid in the magnets. The heat load was 150 watts in the 4.5°K loop, and 16 watts in the 20°K loop, with a vacuum in the 10^{-4} Torr range. It was evident at this time that a small helium leak had developed after cooldown, causing an excessive heat load. After several tests, we found the problem; the spun piece of pipe which makes up the 1Ø helium connection on

C10-2 was leaking at cryogenic temperatures. The spinning of the small diameter pipe created large stresses in the metal, causing it to fracture badly. We were unable to weld the leak shut. Braising the entire surface reduced the leak rate and improved the vacuum by 2 orders of magnitude. This patch, for the time being, is still holding.

On Oct. 16 cooldown was initiated and after a week we had subcooled liquid in the magnets. We ran saturated liquid from the dewar with a slight differential pressure. The liquid was subcooled by the transfer line heat exchange effect, and was 0.02°K below the boiling point at the downstream end of the magnets. The pressure was then dropped 3 psi in the magnet JT, which produced a 2Ø phase fluid with a 0.14°K temperature decrease. The quality of the 2Ø decreases as it flows around the magnets and 1Ø transfer line, returning to the primary cold box with 25% as liquid (see Fig. 2). If sufficient refrigeration had been available, we would have simplified operation by utilizing both cold boxes to refrigerate the dewar, with the liquid helium pump forcing subcooled liquid into the loop.

We ran a set of heat leak data by cutting the flow until we had pure gas returning from the transfer line. Termination of the data run was caused by a loss of refrigeration due to a power outage.

Summary

Valuable experience was gained in how to assemble a transfer line with field welding of the junction boxes; installation and testing being completed in 8 days. In searching for the helium leak, it was necessary to cut the magnet system open several times. For thin wall thickness (1/16") it was easier to cut through the material and make a patch, than to cut open welds and reweld.

In the Accelerator system if a magnet develops a helium leak internally, no attempt should be made to locate <u>or</u> repair it in place. A new pretested magnet should be installed; the old magnet should be repaired in the Lab and cycled to 80°K a minimum of 3 times. If one develops a <u>cold leak</u>, the entire half cell should be removed.

During cooldown, 90% of the specific heat is removed by running 50 to 80°K gas through the 1Ø line, heating it to ambient temperature while returning it back to the compressor. This process takes 4 hours at B12, and about 12 hours for the full service building load. It is the last 5 to 10% that presents the real problem in cooldown. This is the point where the cold box running in the "liquefier" mode can not decrease the temperature further. To continue, one needs to return the cold gas at the appropriate point in the heat exchanger train. At B12, and in the Proto Main, we return it through the 2Ø line. However, even though at B12 we have heat exchanger taps, it still takes 48 hours to remove the last 10%. For the full service building load it is considerably worse, unless of course one dumps several hundred liters per hour of liquid into the system. Instead one could install a one inch vacuum-jacketed return line to destroy the heat exchanger effect of the transfer line between 1Ø and 2Ø. This would give ~36 hours of cooldown without additional liquid consumption.

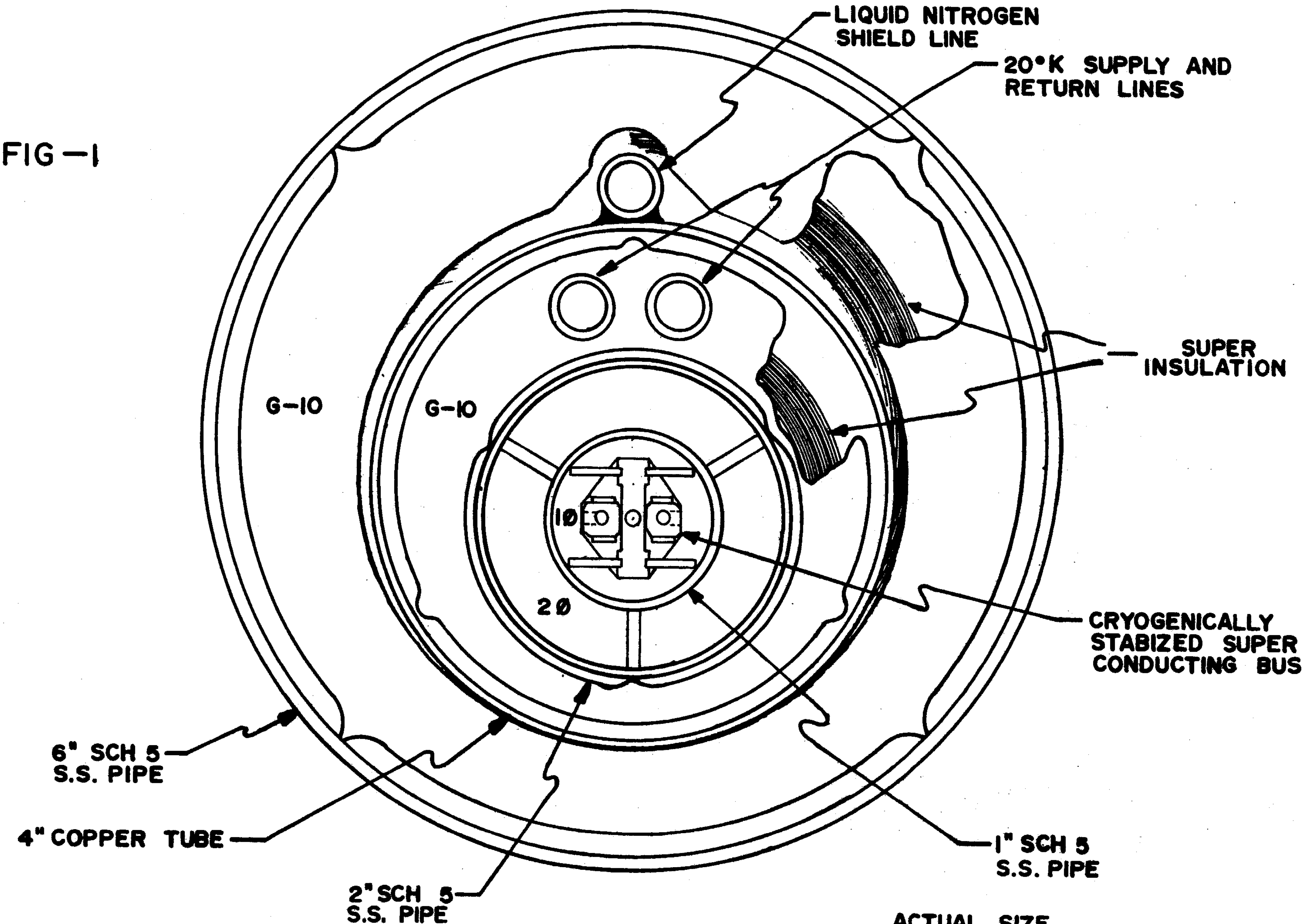
The last major problem is power failures and outages in the Main Ring. We averaged at least one per month. The Doubler will require that if the outage is less than five minutes all equipment, except the main Central Liquefier compressors will start automatically. At the Central Liquefier one would have an automatic recovery compressor to handle return gas.

TABLE I

Measured Data 4.5°K		
Line & C2.5-2	25.±3.W	COLD GAS MEASUREMENTS
Line	<5.W	COLD GAS MEASUREMENTS
C2.5-2	$20.^{+6.}_{-3.}$W	COLD GAS MEASUREMENTS
DEWAR-LINE INTERFACE	7.±3.W	COLD GAS MEASUREMENTS
SYSTEM WITHOUT C10-2	<60.W	LIQUID TO GAS MEASUREMENTS
SYSTEM WITH C10-2	95.±5.W	LIQUID TO GAS MEASUREMENTS
Results 4.5°K		
DEWAR-LINE INTERFACE	7.±3.W	
LINE	<5.W	
C2.5-2	$20.^{+6.W}_{-3.W}$	
C10-2	63.±11.W	
Measured Data 20°K Shield		
LINE	<5.W	
C2.5-2 & C10-2	16.±9.W	

B-12 TRANSFER LINE

FIG-1



ACTUAL SIZE

FIG-2

B-12 FLOW DIAGRAM